A12C-0170

Precipitation Scavenging of Aerosols: Sensitivity of Aerosol Amount to the Spatial and Temporal Distribution of Precipitation

Eric M. Wilcox and V. Ramanathan

Center for Clouds Chemistry & Climate and Center for Atmospheric Sciences
Scripps Institution of Oceanography, University of California, San Diego
9500 Gilman Dr. La Jolla CA 92093-0221
ph: (858) 534-7757; email: ewilcox715@yahoo.com web: /www-c4.ucsd.edu/~ericw/

Abstract

This poster presents a study of aerosol precipitation scavenging, the primary process by which many aerosol species are removed from the atmosphere. The details of this process, which are poorly constrained by observations, may have important consequences for determining the lifetimes of aerosol particles and their ability to be transported far from their sources. This study improves upon previous scavenging computations by incorporating satellite observations of global precipitation at 0.25° resolution and 3 hour temporal sampling into the Model for Atmospheric Transport and Chemistry (MATCH).

Biases are found in the representation of precipitation in MATCH including:

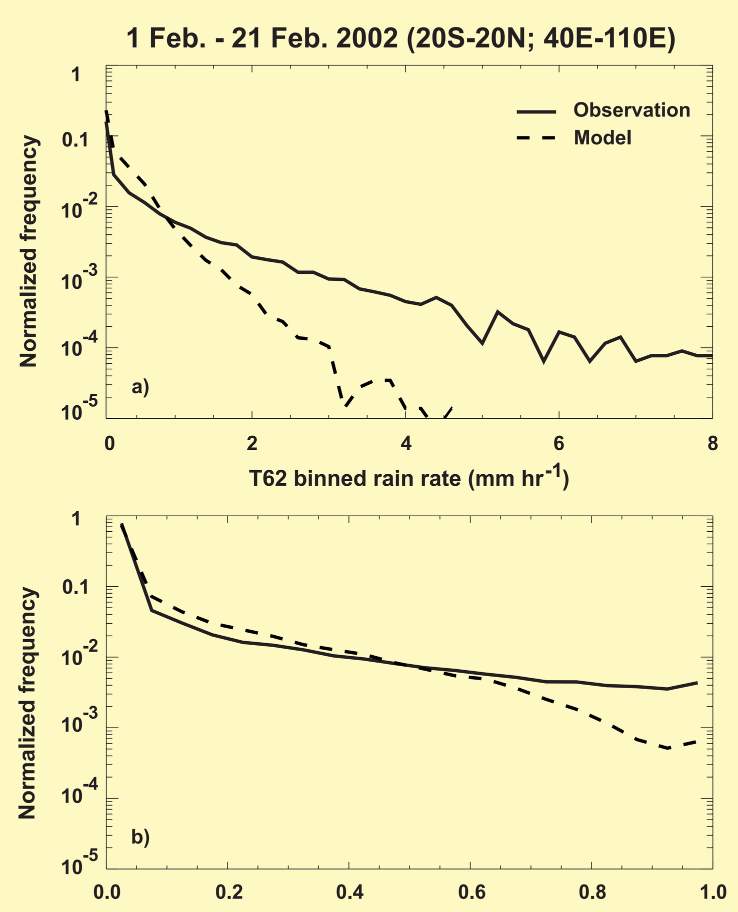
- (a) a bias toward broadly distributed gentle precipitation, resulting in precipitation occurring in a greater number of grid cells and a lack of extreme precipitation events, and
- (b) an bias toward small grid cell precipitating fractions, which results from an incorrect assumption that precipitation associated with deep atmospheric convection always occurs on spatial scales substantially small than a grid cell.

Simulations are performed to test the impact of these biases which reveal that:

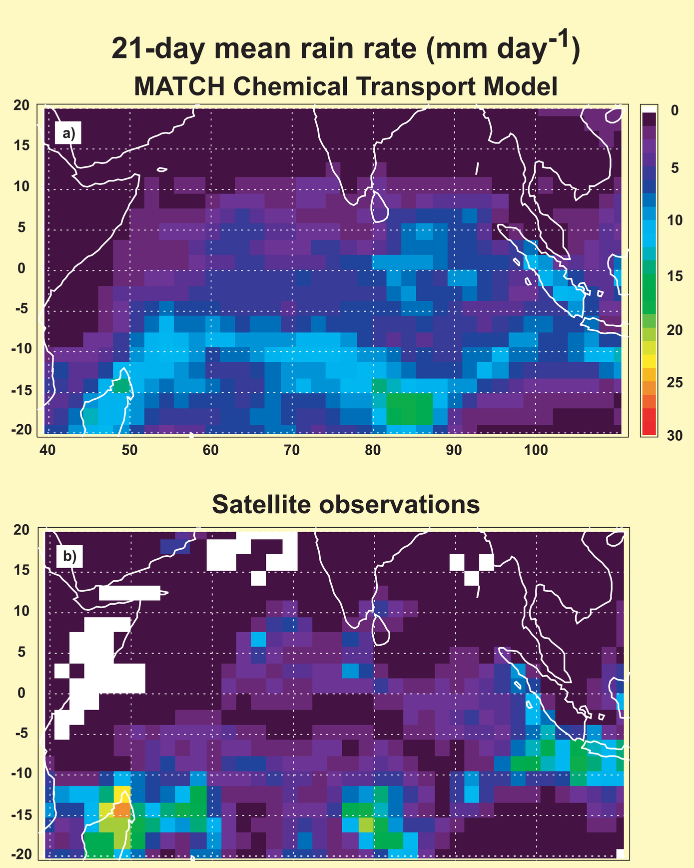
- the impact of the rain rate bias occurs primary where the model simulates precipitation, but little or none was observed, such as the edges of the ITCZ region,
- therefore the ITCZ aerosol gradient in the Indian Ocean is sharper when observed precipitation is applied,
- the impact of the grid cell precipitating fraction bias results in an overestimate in ITCZ aerosol and a greater than factor of 2 overestimate in aerosol exported from India to the rest of the Northern Hemisphere.

Model Biases in the Distribution of Precipitation

- **Rain rate bias:** Grid cell averaged rain rates are biased toward gentle rain events in the model.
- Extreme precipitation events associated with mesoscale organized convective systems are absent in the model.
- **Precipitating fraction bias:** In a common parameterization of aerosol scavenging, grid cells filled greater than 80% with precipitation occur one order of magnitude less frequently.
- Extreme events are mesoscale organized convective systems that are as large or larger than model grid cells.



Frequency distributions of (a) rain rate (in mm hr^{-1}), and (b) grid cell precipitating fraction. Solid lines are observations from a multi-platform satellite data set. Dashed lines are simulated rain rates from the MATCH global atmospheric model. All are averages over MATCH grid boxes at T62 resolution.

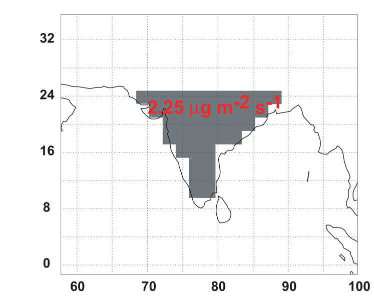


Feb. 1-21, 2002 mean rain rate over the Indian Ocean basin in (a) the MATCH simulation and (b) the satellite observations. Rain rates are in mm day^{-1} and averaged over MATCH grid boxes at T62 resolution.

- Simulated precipitation is more broadly distributed over the Tropical Indian Ocean ITCZ region.
- 80% of model grid cells experience precipitation while only 29% of observed grid cells do.
- Regions of greatest precipitation occur in approximately the proper regions, although grid cell averaged rain rates are lower.

Methodology

- Simulations using aerosol scavenging based on simulated and observed precipitation are performed to test the impact of model biases on (1) **rain rate**, and (2) **grid cell precipitating fraction**
- A series of 5 simulations - each 21 days in length.
- Using the Model for Atmospheric Transport and Chemistry (MATCH)[1].
- A Steady uniform source of idealized aerosol species at 2.25 $\mu g\ m^{-2}\ s^{-1}$ is imposed on the bottom layer of the model over India.



Shaded MATCH grid cells indicate the location of the steady, uniform aerosol source in the bottom layer of the model. Source rate is 2.25 $\mu g\ m^{-2}\ s^{-1}$.

MATCH Chemical Transport Model

- Simulates sources, sinks and advection of aerosol and trace gas species at T62 grid cell spacing and 28 vertical levels.
- Assimilates NCAR/NCEP reanalysis data set every 3 hours.
- **Convection** is parameterized using Zhang and McFarlane (1995)[2] scheme (same as CCM3), and is responsible for most precipitation, particularly in the Tropics.

Satellite Precipitation Measurements

- Real-time three-hourly multi-platform data set of Huffman *et al.* (2001)[3].
- SSM/I and TRMM Microwave Radiometer data (where available); TRMM-tuned geostationary IR data elsewhere.

Scavenging Computations

Precipitation scavenging is computed based on a scheme similar to that of Giorgi and Chameides[4]:

$$\frac{\Delta n}{\Delta t} = \frac{nF_p}{\Delta t}$$

F_p is the grid cell fraction of aerosol scavenged. Often approximated as the **grid cell fraction of precipitation.**
n is the grid cell mass mixing ratio of aerosol.
Δt is the model time step.

$$F_p \propto \frac{\dot{Q}}{L}$$

$\dot{Q}$ is the production rate of rain water.
L is the condensed water amount.

Summary of Simulations

name	precipitation source	scavenging computation	
STD	MATCH	$\dot{Q}$ and L from MATCH	
NOSCAV	not appl.	not appl.	
SAT1	satellite	$\dot{Q}$ from satellite*	tests rain rate bias.
SAT2	satellite	F_p from satellite	tests precip. fraction bias.
SAT3	satellite	F_p from satellite	tests precip. fraction bias and ice phase scavenging.

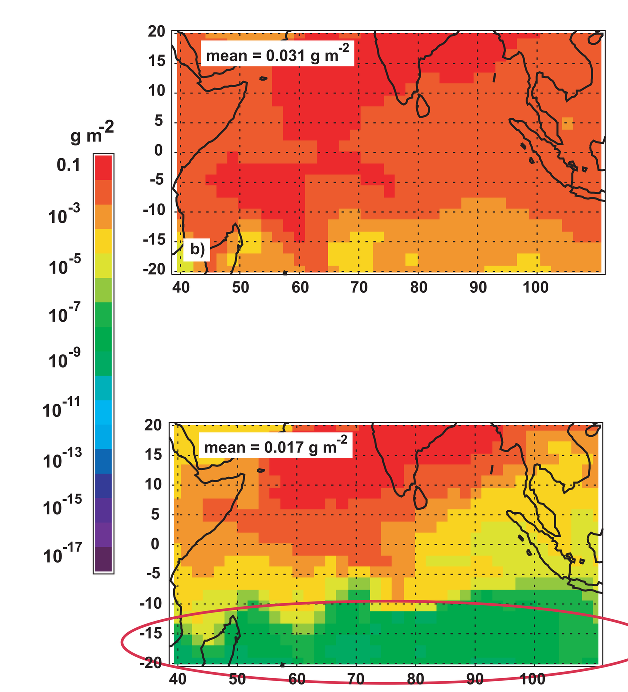
* extrapolated from vertically integrated $\dot{Q}$ observed by satellite.

[1] Rasch, P. J., N. M. Mahowald, and B. E. Eaton, *J.Geophys.Res.*, **102**, 28127-38, 1997.
[2] Zhang, G. J. and N. A. McFarlane, *Atmos.-Ocean*, **33**, 407-446, 1995.
[3] Huffman,G.J., *et al.*, Proc. 11th AMS Conf. Satellite Meteor. and Oceano., Madison, Wisc., 2001.
[4] Giorgi, F. and W. L.Chameides, *J. Geophys. Res.*, **91**, 14367-76, 1986.

Simulated Aerosol Distributions

Aerosol burden after 21 days ($g\ m^{-2}$)

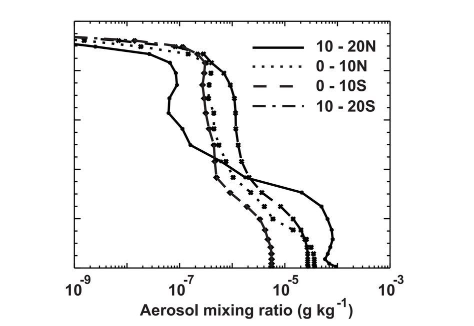
Aerosol profiles after 21 days ($g\ kg^{-1}$)
40 - 110E longitude



No precip. scavenging (NOSCAV)

In the absence of aerosol scavenging:

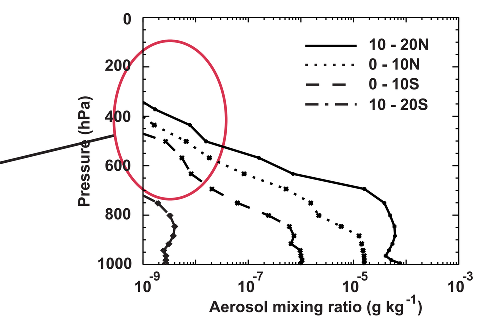
- Uniformly high aerosol amounts occur throughout the Indian Ocean region.
- Aerosol spreads well south of the equator.
- An upper bound on aerosol amount is established.



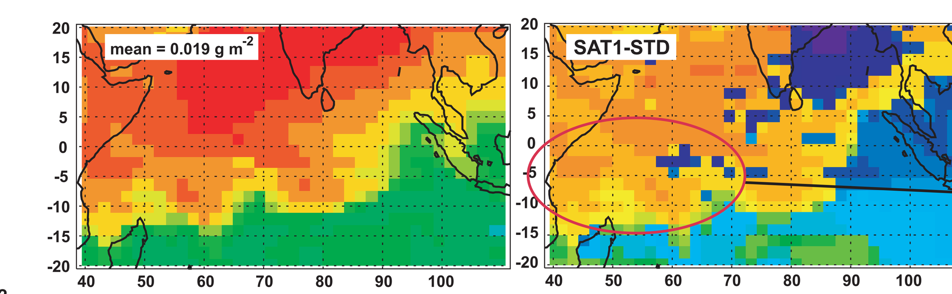
Scavenging from simulated precip. (STD)

Based on simulated precipitation:

- About 45% of Indian Ocean aerosol is removed.
- Significant removal occurs over the ITCZ region.
- Upper-tropospheric amounts are also reduced.

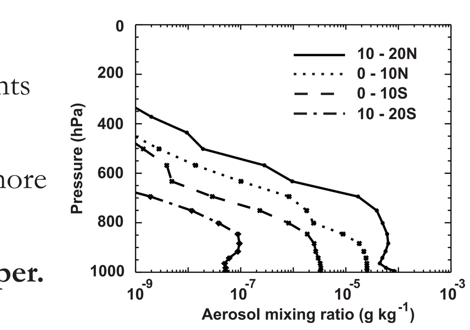


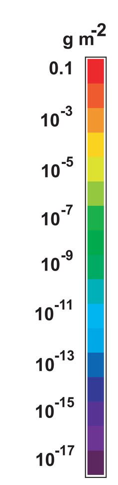
Scavenging based on observed rain rates (SAT1)



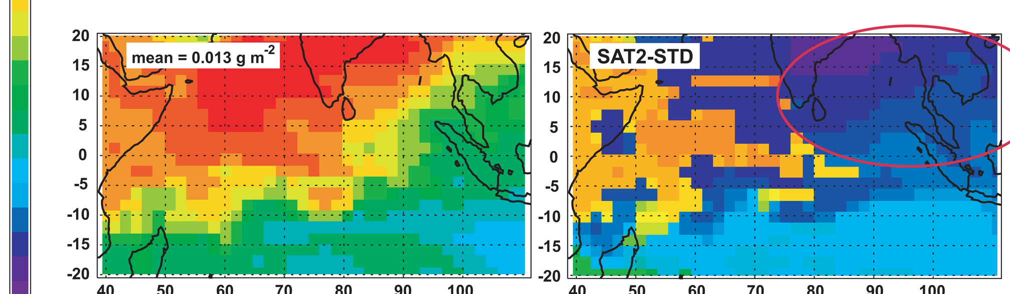
Using observed rain rates:

- Slightly higher total Indian Ocean aerosol amounts compared to STD simulation.
- Significant differences at edge of ITCZ where more precip. is simulated than observed.
- As a result, the **ITCZ aerosol gradient is sharper.**



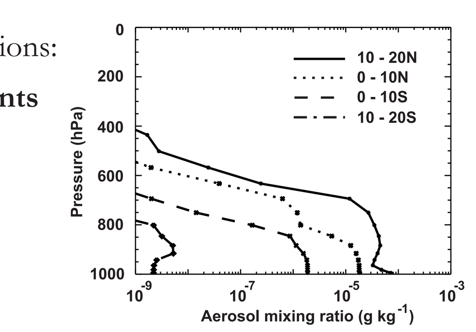


Scavenging based on observed grid cell precipitating fraction (SAT2) (liquid phase scavenging only)

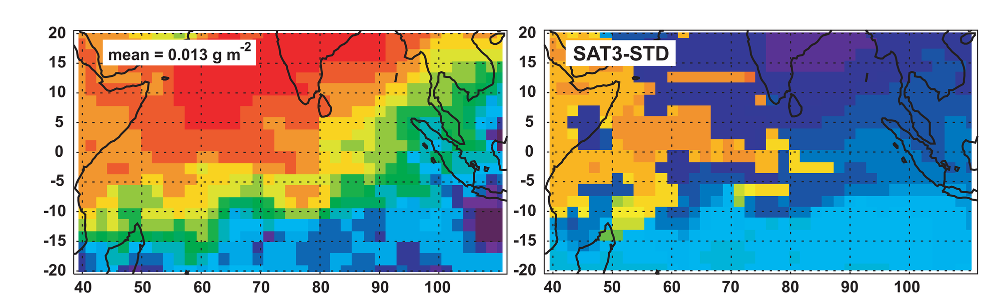


When accounting for larger grid cell precipitating fractions:

- **Bay of Bengal and East Asian aerosol amounts significantly reduced compared to STD simulation.**
- ITCZ aerosol amounts are further reduced.
- Upper-tropospheric aerosol amounts are further reduced in the equatorial and ITCZ regions.

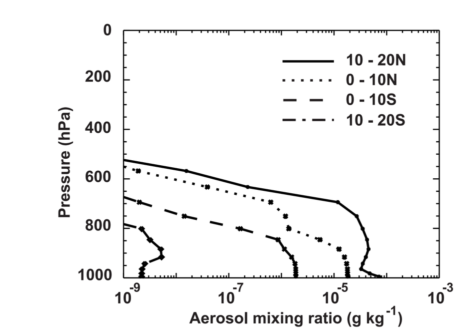


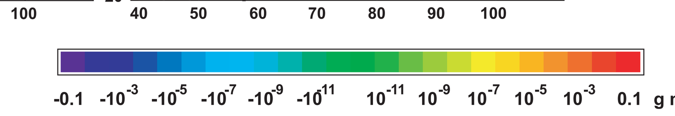
Scavenging based on observed grid cell precipitating fraction (SAT3) (liquid and ice phase scavenging)



When ice phase scavenging is included:

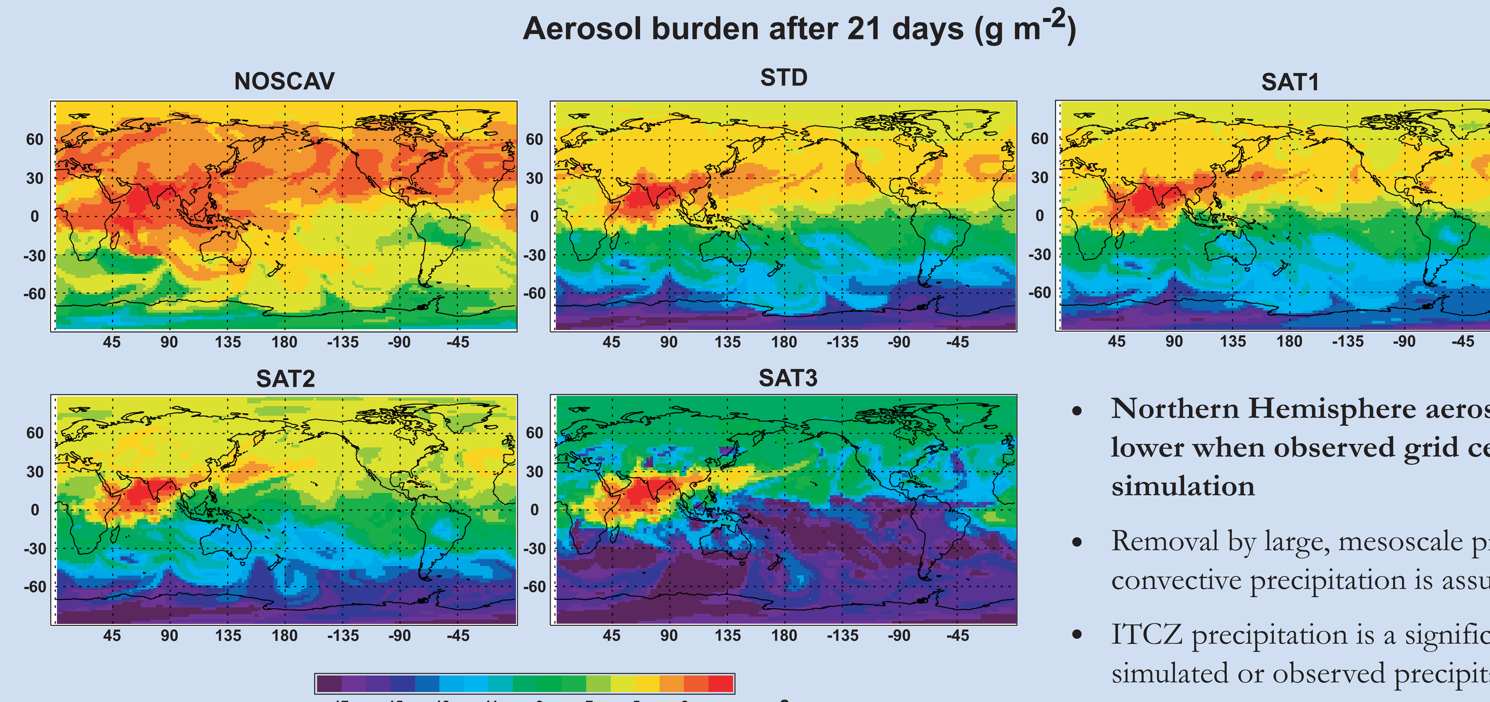
- Aerosol over Indonesia is virtually eliminated.
- Upper-tropospheric aerosol amounts further reduced, even north of ITCZ region.





Long-range Transport of Aerosols

Aerosol burden after 21 days ($g\ m^{-2}$)



Hemispheric-mean aerosol burden after 21-days ($mg\ m^{-2}$) excluding Indian Ocean region (20S-20N; 30E-120E).

	Northern Hemisphere	Southern Hemisphere
STD	2.0	0.002
NOSCAV	9.6	1.0
SAT1	1.8	0.004
SAT2	0.8	4.7×10^{-4}
SAT3	0.7	4.5×10^{-4}

- **Northern Hemisphere aerosol exported from the Indian Ocean region is a factor of 2 lower when observed grid cell precipitation fraction is used, compared to the STD simulation**
- Removal by large, mesoscale precipitation structures is not captured in standard models because convective precipitation is assumed to occur on scales much smaller than model grid cell.
- ITCZ precipitation is a significant barrier to transport to the Southern Hemisphere whether simulated or observed precipitation is applied.